# Experimental Study of Large-Scale Bearing Force Mechanics in Highlands Lunar Regolith Simulant

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SPACE RESOURCES ROUNDTABLE

# Introduction

How can we measure bearing capacity at scale in a regolith simulant?

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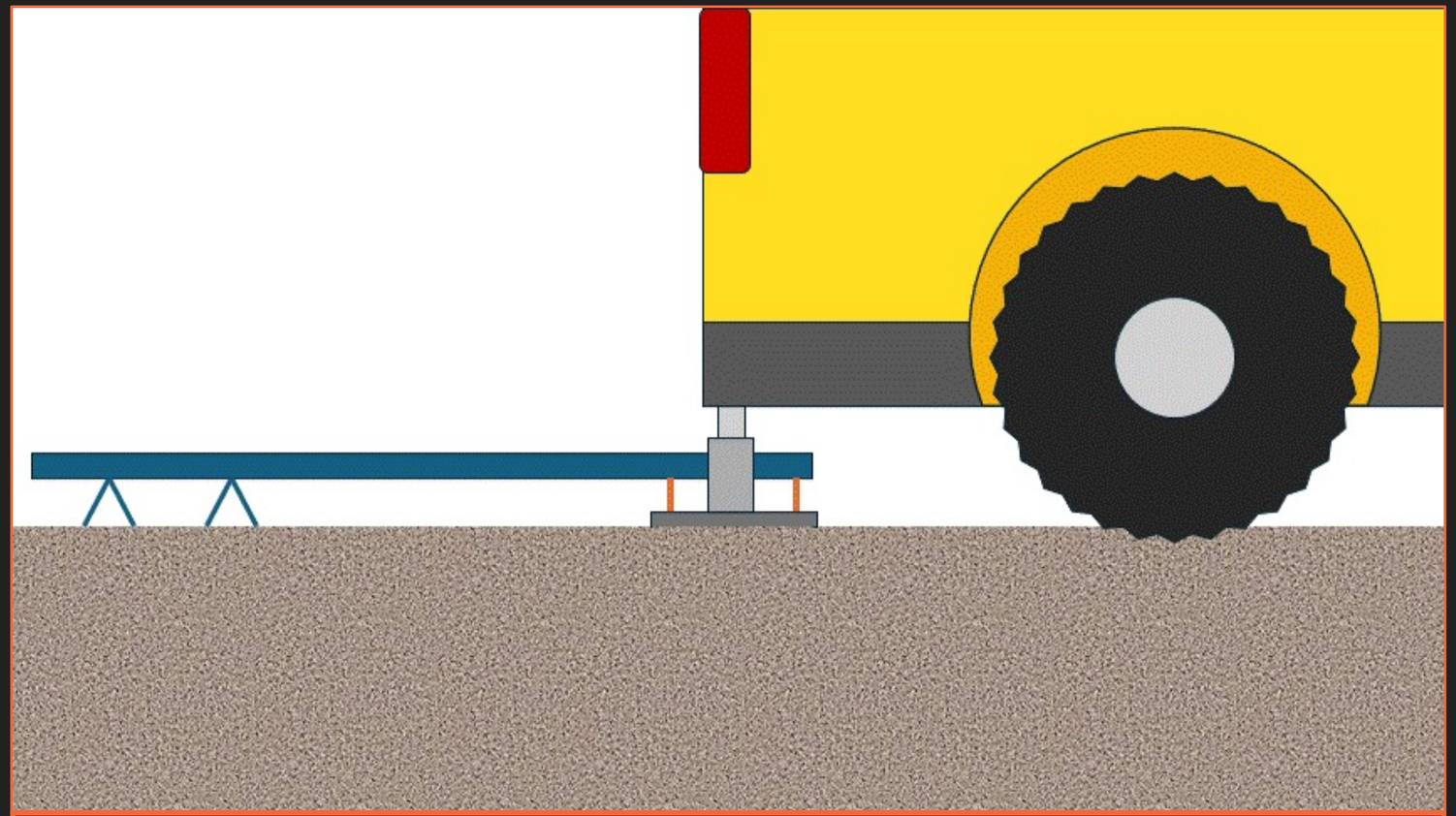
# Bearing Capacity Field Test

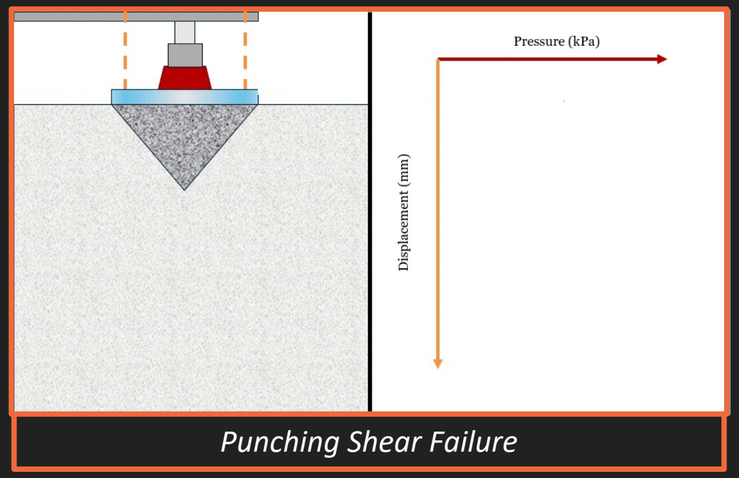
- ASTM D1195
  - Used for foundation analysis
  - Requires heavy equipment
  - Measures force vs displacement
  - Loaded steel plate
    - Determines the max load before failure
    - Data plots a “Load Settlement Curve”



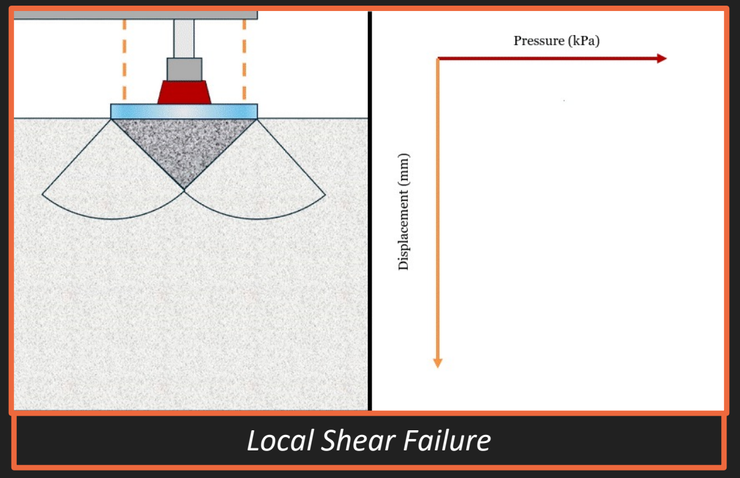
*Example of Terrestrial Bearing Capacity Test*

# Load Settlement Curves

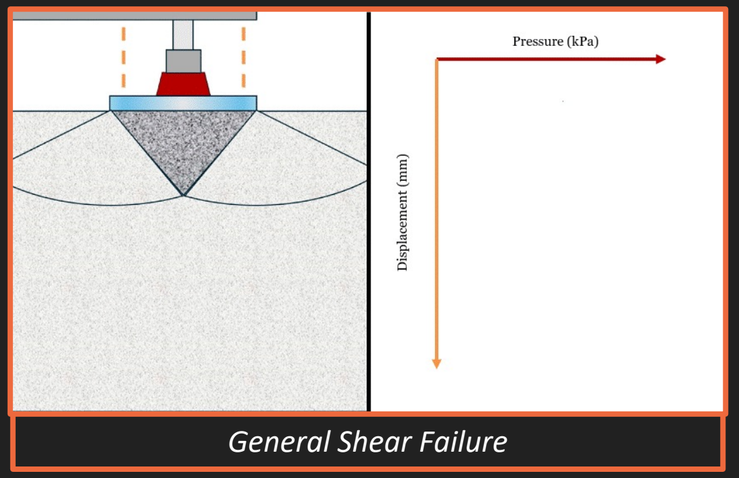
- Show applied pressure (x) vs depth (y)
- 3 kinds of characteristic “Failure” in bearing capacity testing




*Punching Shear Failure*

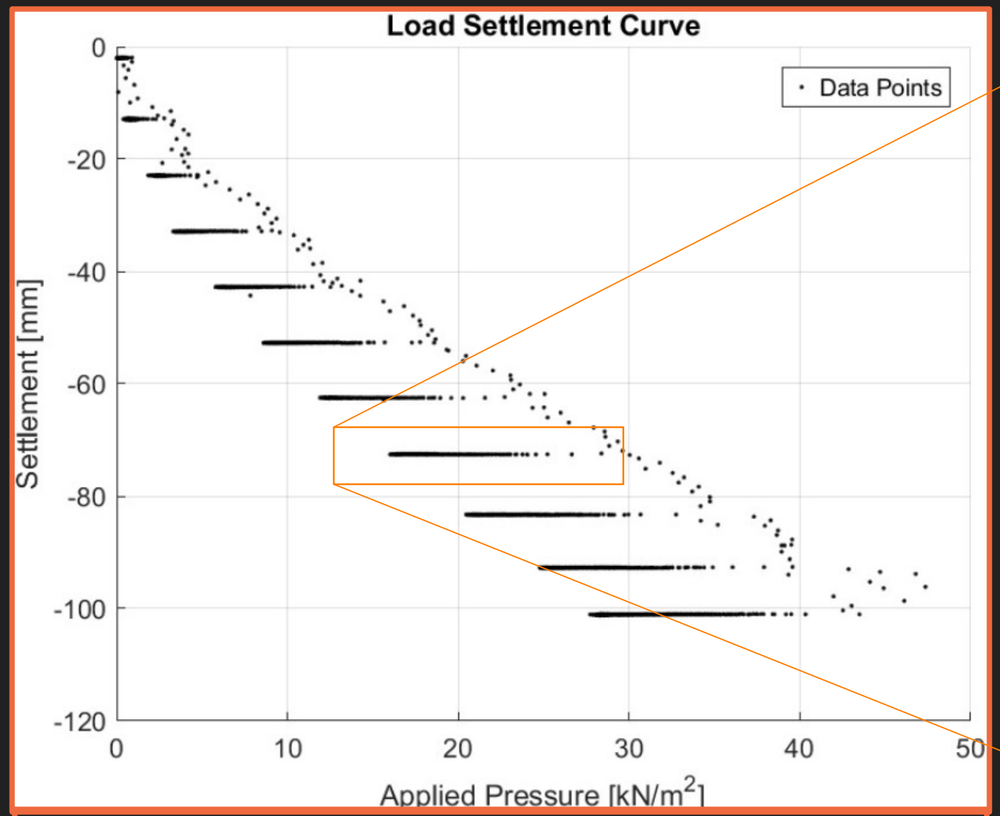



*Local Shear Failure*

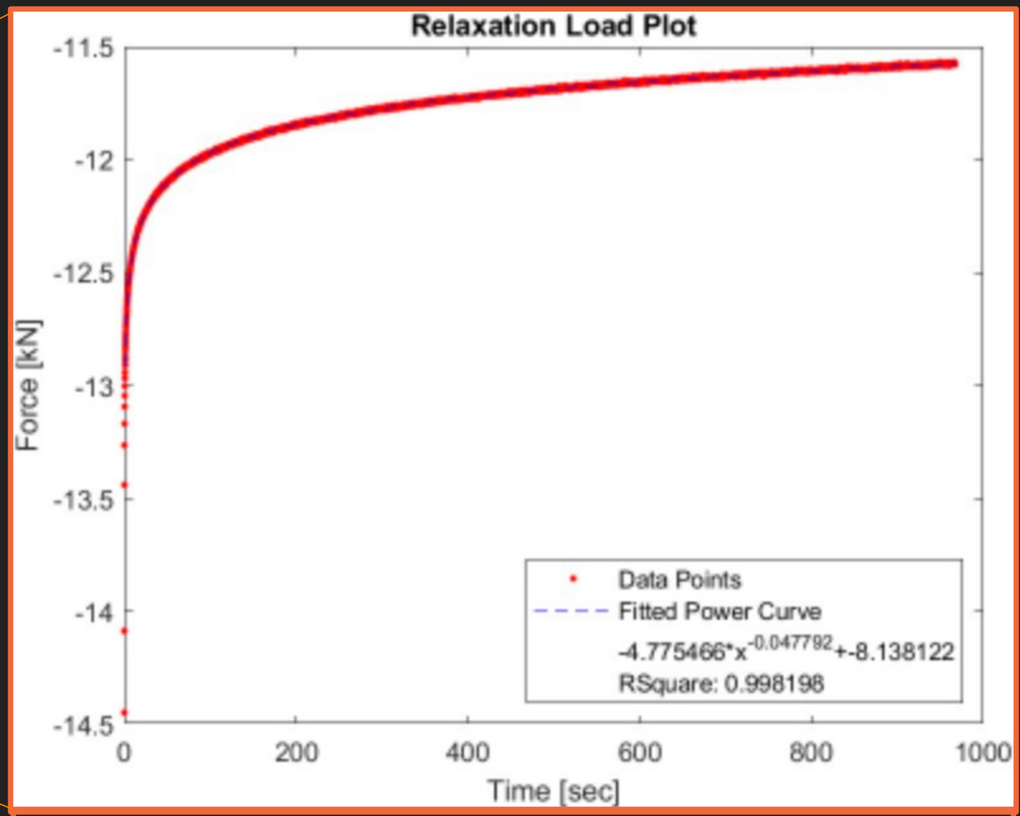



*General Shear Failure*

# Soil Relaxation



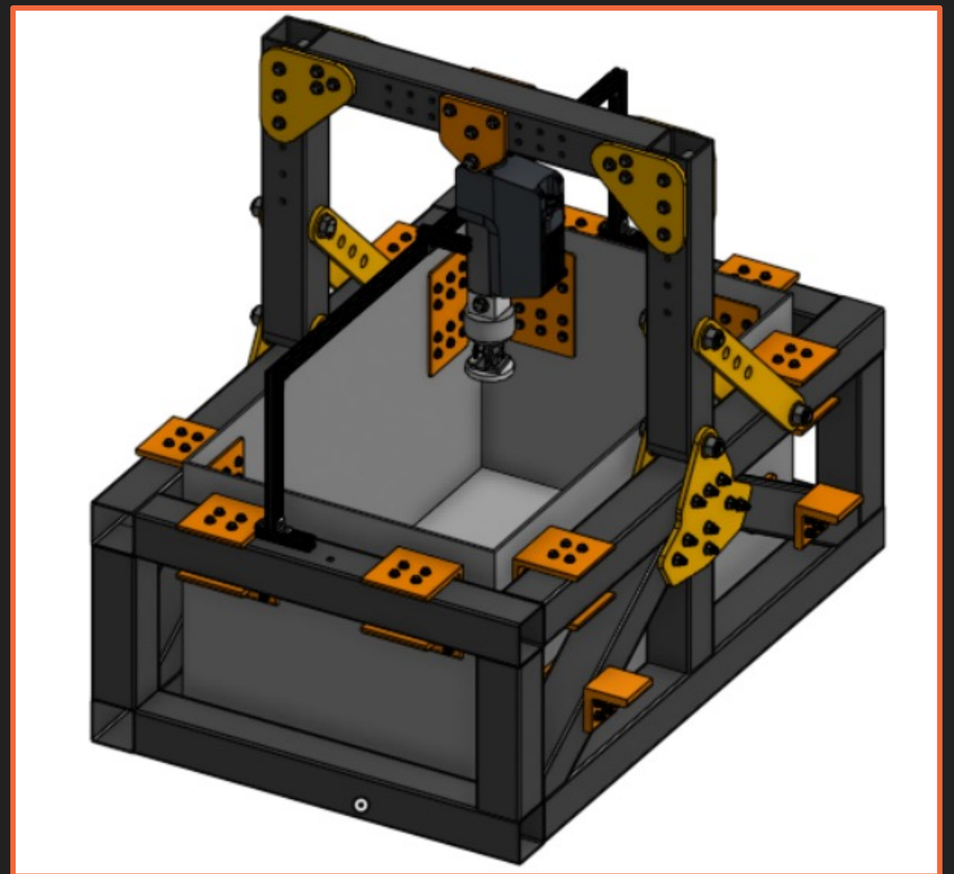

*Example Load Settlement Curve*




*Example of Soil Relaxation*

# Test Campaign

- Test using MTU-LHT-1A
- Perform test according to ASTM D1195
- Test in atmosphere (atm or A) and vacuum (vac) chamber
- 3 initial Bulk Densities, 3 replicates
  - 1.4 g/cm$^3$ (“fluffy”)
  - 1.6 g/cm$^3$ (“average”)
  - 1.8g/cm$^3$ (“dense”)
- Measured Parameters
  - Plate displacement (LVIT)
  - Force (Load Cell)
  - Subsurface pressure (1.6 and 1.8 atm tests, pressure blanket)
  - Surface displacement (atm tests, Handheld LiDAR system)



*HERCULES Test Frame Render*

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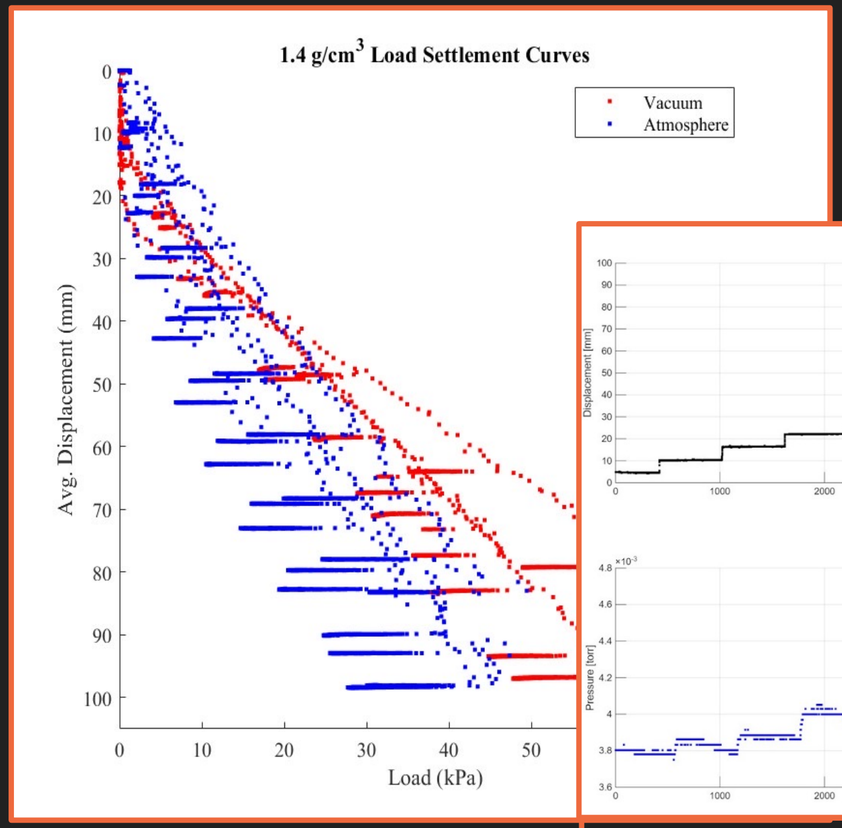
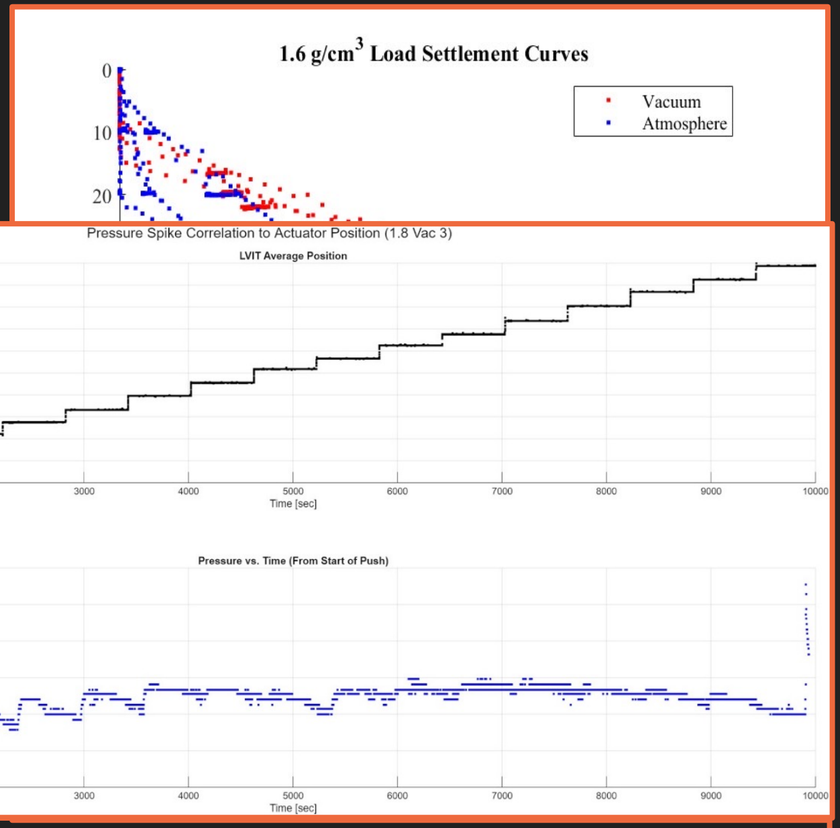
# Load Settlement Curves

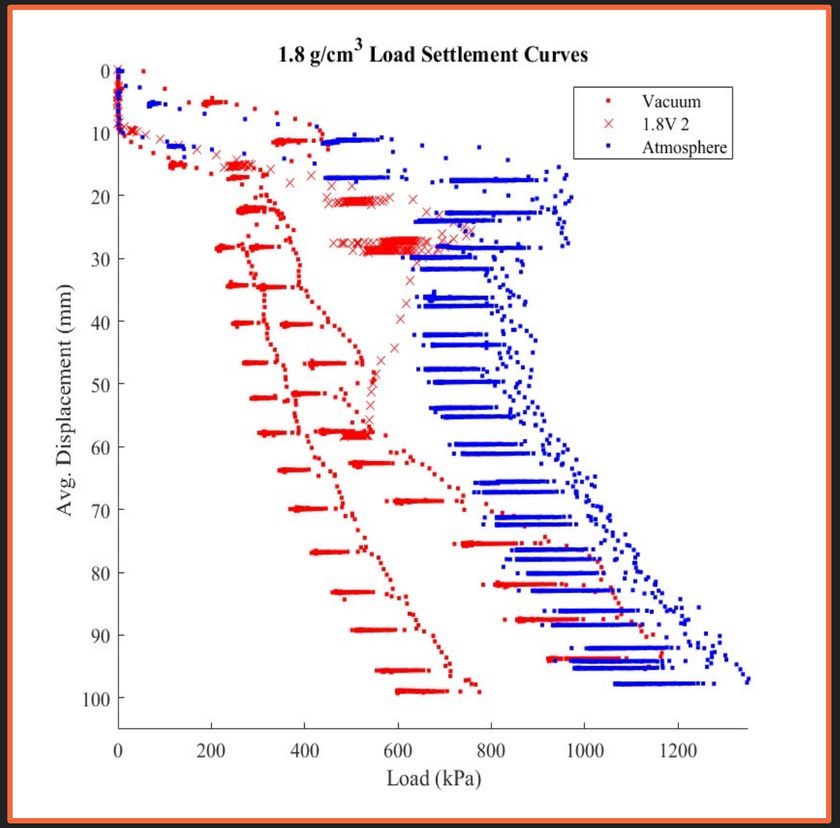


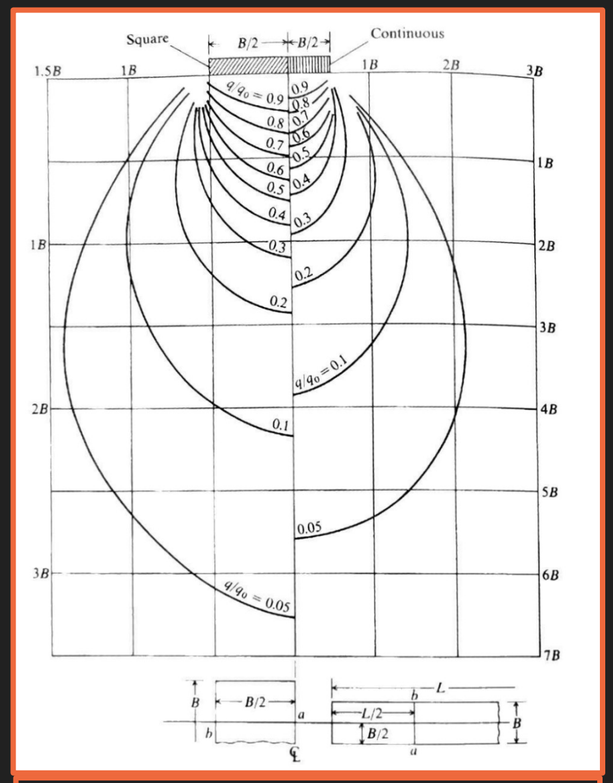




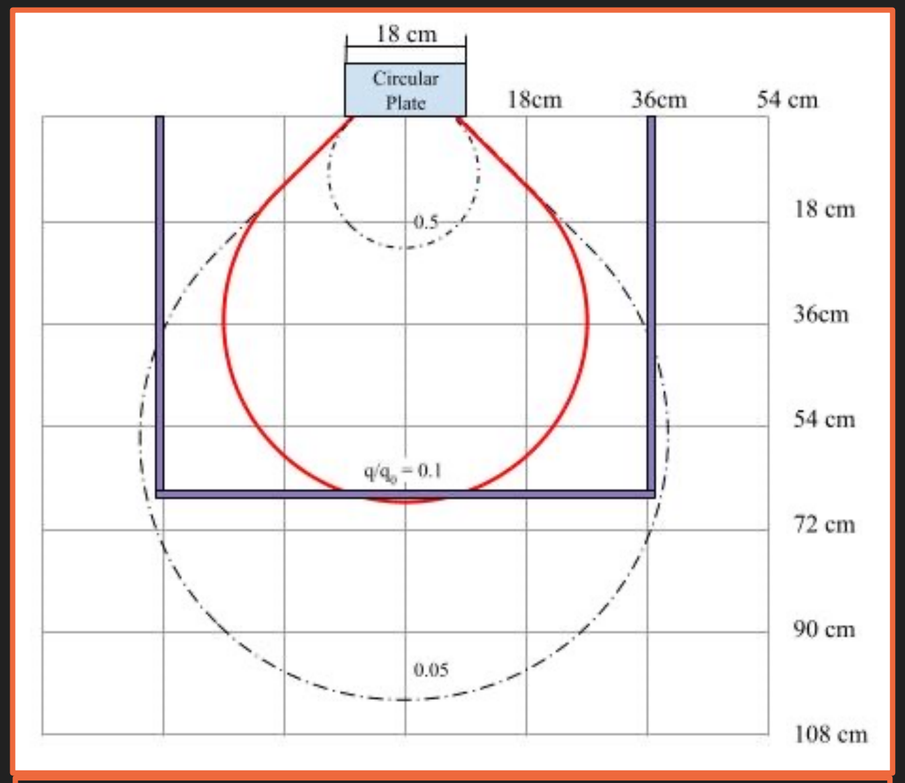
*Actuator disp. and Chamber Pressure plots*



# Pressure Bulb (Boussinesq Equation)




*Pressure Isobars from Boussinesq Eqn*




*Dimensioned Pressure Bulb and Bin*

- Edge effects
- Pressure isobars (bulbs)
  - Subsurface distribution of pressure
  - Dependent on plate size and geometry
- 60cm (h) x 72 cm (w) x 120cm (l) Bin

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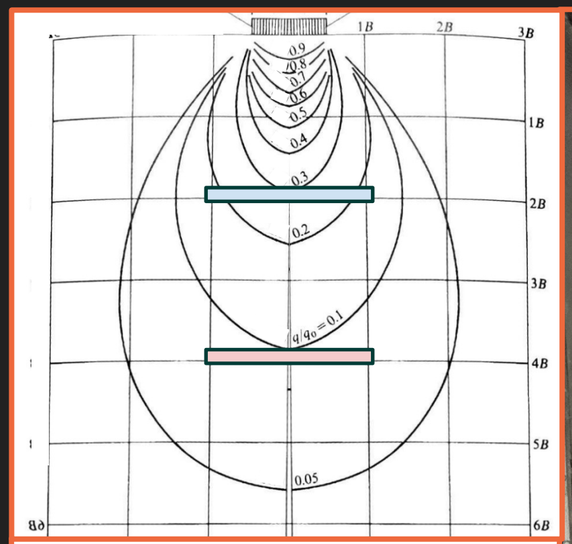
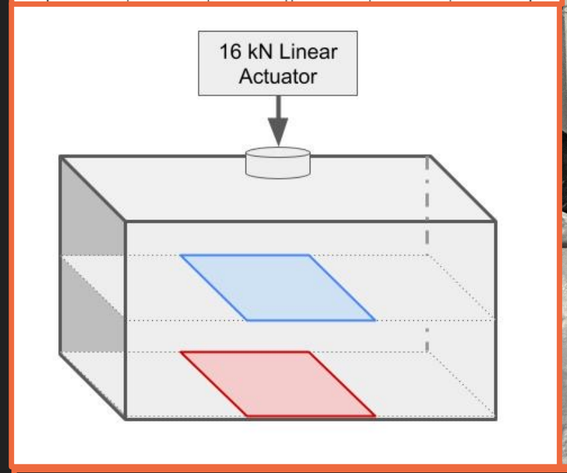
# Pressure Test Setup




*Pressure Blanket Placement in HERCULES Bin*

- 48.77 cm x 42.67 cm (19.5” x 17”) pressure sensing mat (blanket)
- 48 x 42 grid of sensors
- 41 kPa (6 psi) max pressure
- Constant reading through test
- 3 Test setups, 1 replicate
  - No blanket
  - Blanket in the bottom of the bin
  - Blanket in the middle of the  bin
- Only used for 1.6 and 1.8 g/cc atmospheric tests

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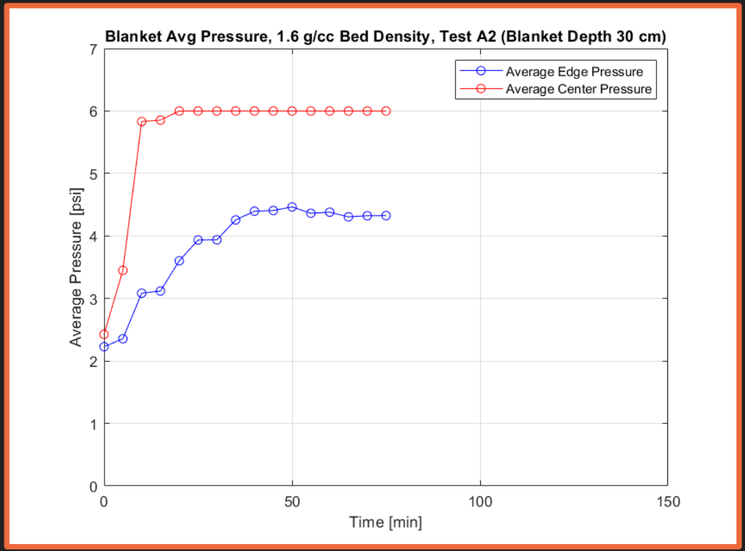
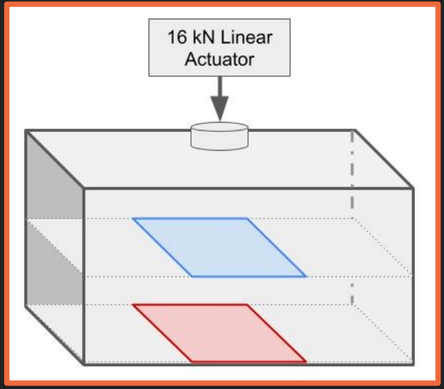
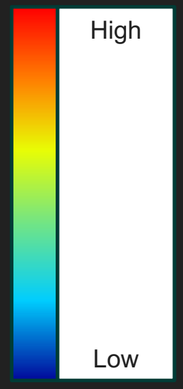
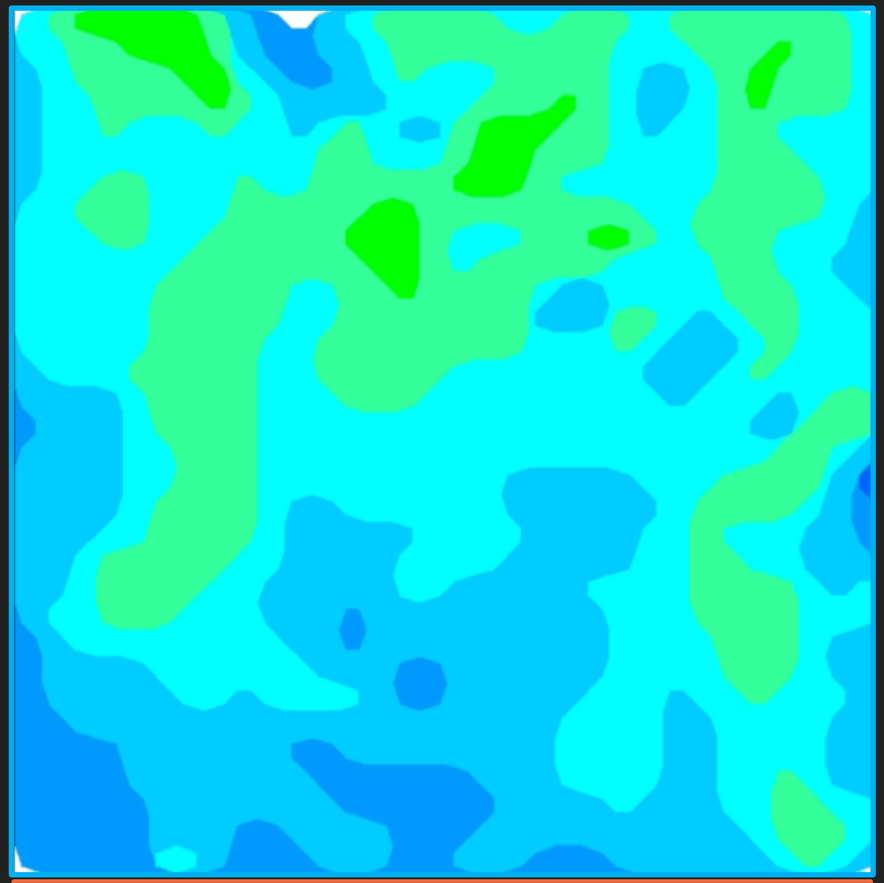
# Middle of 1.6 Bin



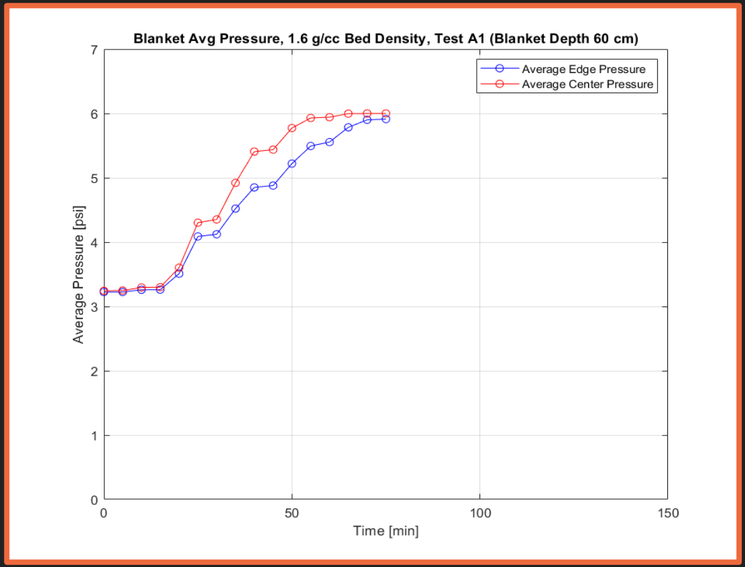



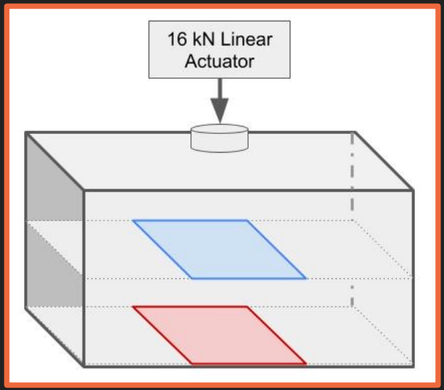
*1.6g/cc Middle of Bin Full Test GIF from Pressure Blanket*

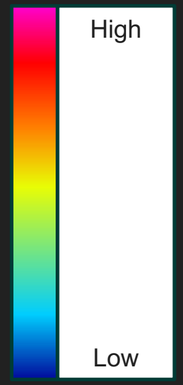
| Push # | Applied Pressure | Expected Pressure (center) | Measured Pressure (center) | Expected Pressure (edge) | Measured Pressure (edge) |
|---|---|---|---|---|---|
| 0 | 0 | -- | 2.4 | -- | 2.2 |
| 1 | 3.5 | 3.45 | 3.5 | 2.9 | 2.3 |
| 3 | 17.7 | 7.71 | 6.0 [max] | 5.74 | 3.9 |
| 5 | 25 | 9.9 | 6.0 [max] | 7.2 | 4.5 |
| 7 | 32 | 12 | 6.0 [max] | 8.6 | 4.3 |

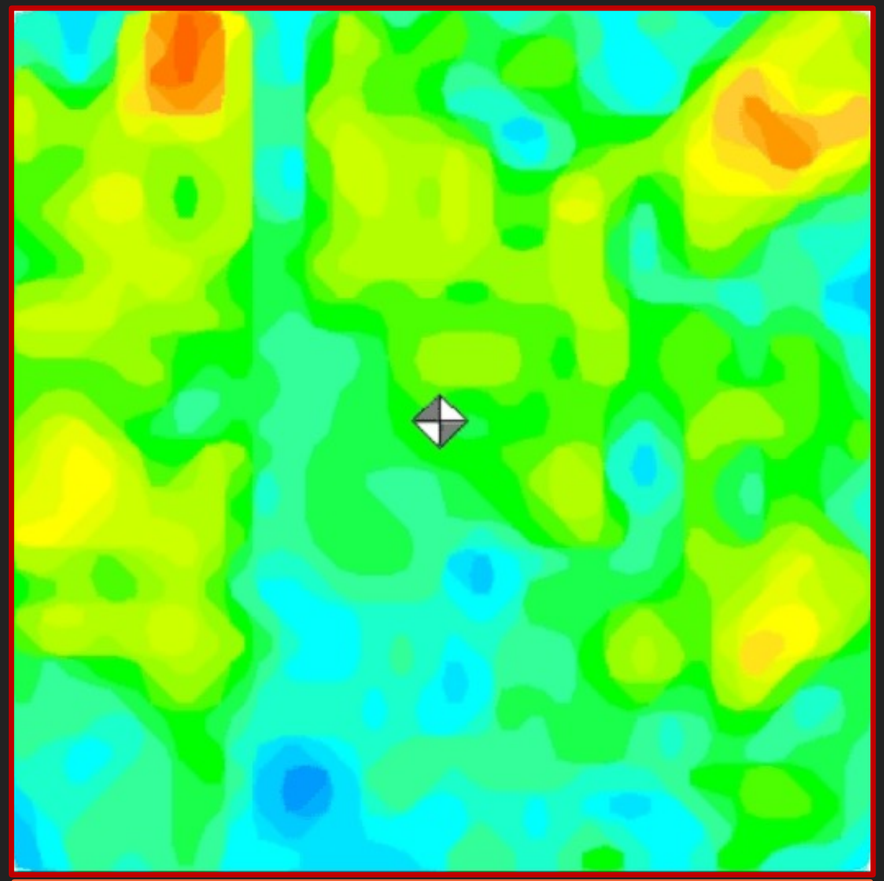
*All values measured in psi*

# Bottom of 1.6 Bin



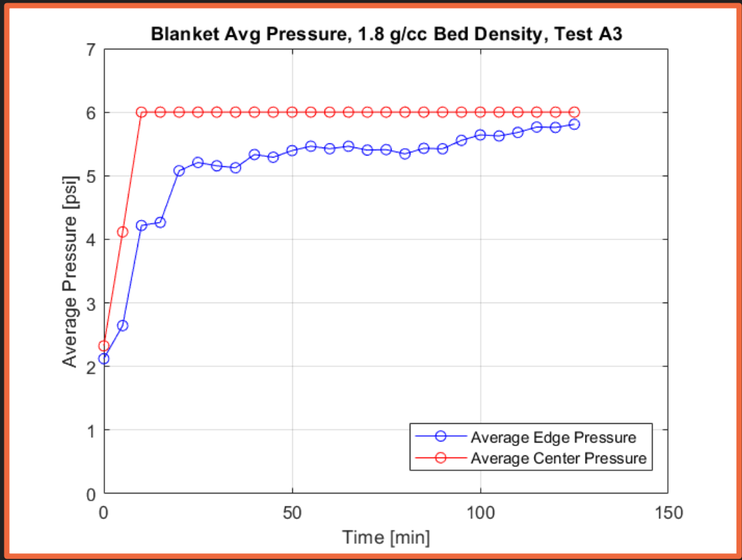



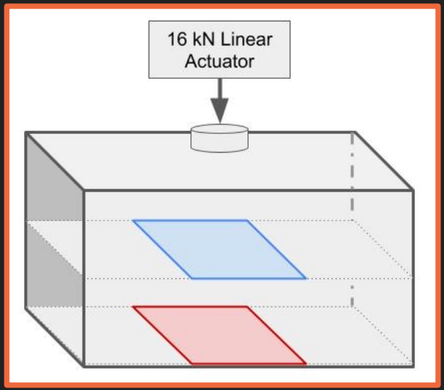
*1.6g/cc Bottom of Bin Full Test GIF from Pressure Blanket*

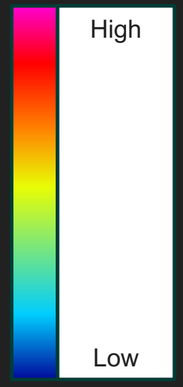
| Push # | Applied Pressure | Expected Pressure (center) | Measured Pressure (center) | Expected Pressure (edge) | Measured Pressure (edge) |
|---|---|---|---|---|---|
| 0 | 0 | -- | 3.2 | -- | 3.2 |
| 1 | 0.42 | 3.242 | 3.2 | 3.221 | 3.3 |
| 3 | 8.40 | 4.04 | 4.3 | 3.62 | 4.1 |
| 5 | 20.6 | 5.26 | 5.8 | 4.23 | 5.2 |
| 7 | 30.45 | 6.245 | 6.0 [max] | 4.7225 | 6.0 [max] |

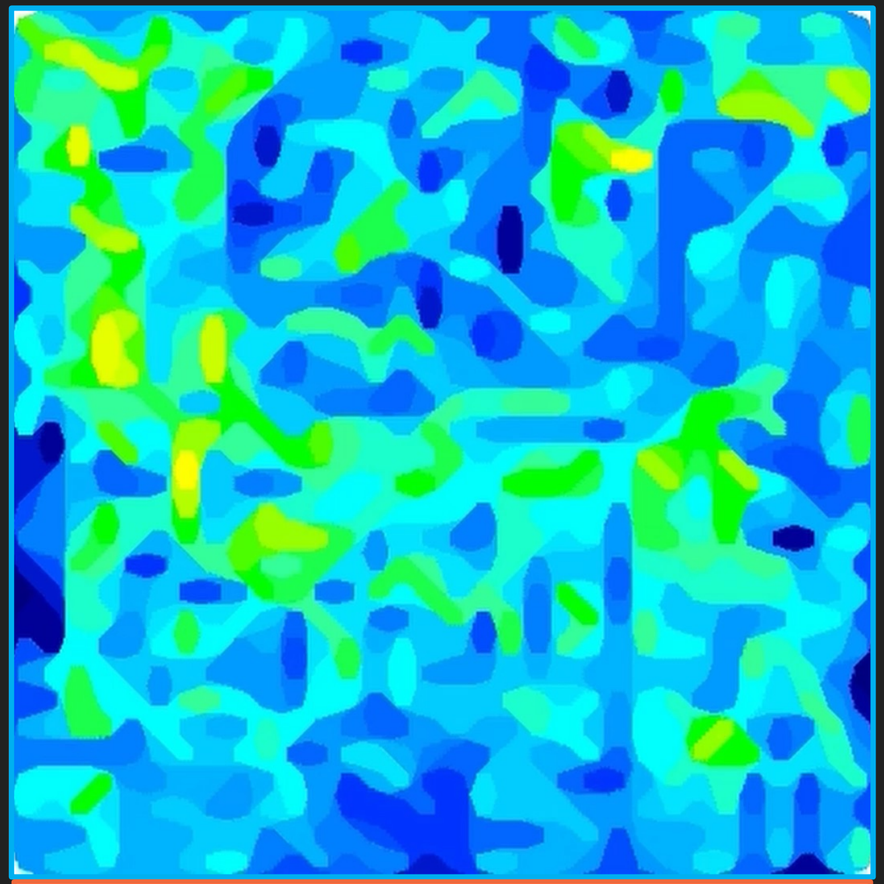
*All values measured in psi*

# Middle* of 1.8 Bin



*1.8g/cc Middle of Bin Partial Test Video from Pressure Blanket*

| Push # | Applied Pressure | Expected Pressure (center) | Measured Pressure (center) | Expected Pressure (edge) | Measured Pressure (edge) |
|---|---|---|---|---|---|
| 0 | 0 | -- | 2.3 | -- | 2.1 |
| 1 | 16.0 | 6.336 | 4.1 | 5.3 | 2.6 |
| 3 | 98.9 | 31.206 | 6.0 [max] | 21.88 | 5.3 |
| 5 | 95.4 | 30.156 | 6.0 [max] | 21.18 | 5.4 |
| 7 | 98.2 | 30.996 | 6.0 [max] | 21.74 | 5.5 |

*All values measured in psi*

# Pressure Blanket Data Summary

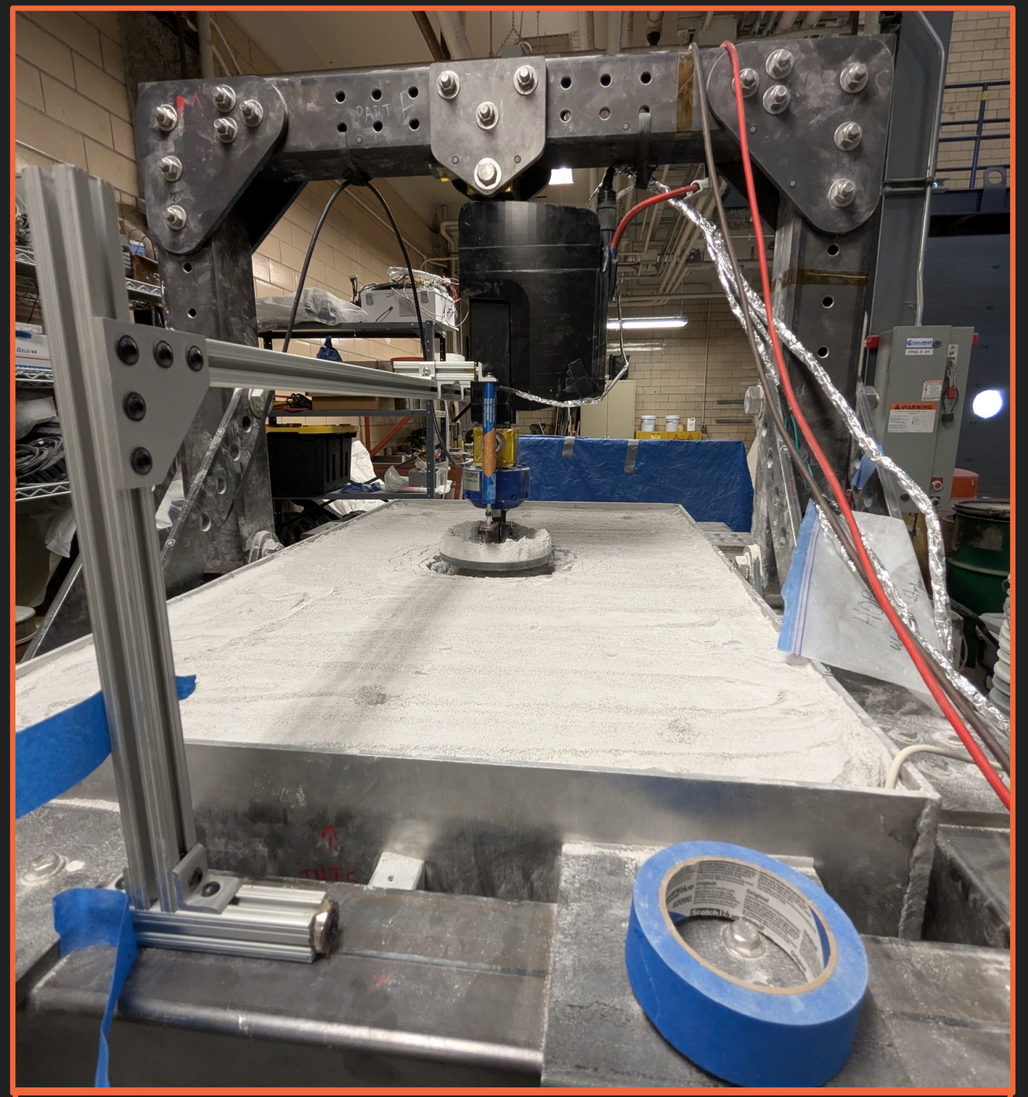
Space Resources Roundtable

## Results

- Lower than expected pressure in middle of bin

## Future Work/Analysis

- Determine “size” of stress bulb from mat measurements
- Test how pressure increases against the sidewall
- Test with higher max-pressure blanket



*HERCULES Post-Test*

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# Acknowledgements


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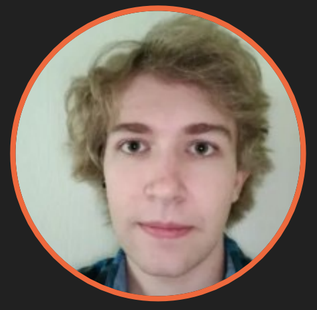

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